Name ______________________________________ AP Chemistry

Models of Hydrogen Atom

One of the most tantalizing puzzles at the beginning of the 1900s was how to describe the atom. In your summer work, you review the basic components of an atom (proton, neutron, electrons). Today, using a simulation, you are going to learn and explore different models proposed by scientists on the arrangement of the atom. These models include:

- Niel Bohr's *Shell* model
- Erwin Schrodinger's *Quantum Mechanical* model

Experimental Emission Spectrum

1) Go to the following link: http://phet.colorado.edu/en/simulation/hydrogen-atom. Click on "Run Now" below the image.
2) Turn on the *White* light gun.

The white light is shining into a transparent box containing hydrogen gas. This is the ?-box. The gas molecules have been separated so hydrogen atoms are present, but the scientists cannot see these individual atoms (hence the "?"). It is possible, however, to send light into the box and record the light that is emitted from the box.

3) Turn the spectrometer on to observe which photons of light are emitted from the transparent box. After allowing the light to pass through the transparent box for a few minutes, what regions of the electromagnetic spectrum are being emitted?

4) In the light controls, click on *Monochromatic*. Notice that the incoming photons are all the same color now. A spectrum slider appears that allows you to change the energy of the incoming photons. Move the slide from UV to IR. Are there any photons emitted as you move the slider from one region to the other?

5) Recall the relationship between wavelength, frequency, and energy based on the following equation: $E = hf$ (where $h = 6.626 \times 10^{-34}$ Js) and $c = \lambda f$.
   (a) If a photon of monochromatic light has a wavelength of 94 nm, what is its frequency (remember the units are sec^{-1})?

(b) What is the energy of this photon?

6) Switch the Light Controls back to *White* light. Move the *Slow…Fast* slider all the way to *Fast* and click on "Reset" on the spectrometer. Let the simulation run for a few minutes until the red column is at the top. Describe/draw the experimental emission spectrum for atomic hydrogen below. Include the regions/colors of the electromagnetic spectrum, approximate wavelength, and quantity of photons at each wavelength (each circle equals one photon).

The emission spectrum for hydrogen is a very important experimental observation used to support (or refute) different models of the hydrogen atom. Scientists cannot "look" inside the ?-box of hydrogen and actually see an atom. Instead, they construct theories and conceptual models to explain observations related to the atom. Models can be tested with experiments to learn if the model is useful for predicting how nature behaves.

Bohr's Model

1) Switch to "Prediction" and choose Bohr on the menu to the left. Click on "Show electron energy level" in the upper right hand corner and set the speed on the *Slow…Fast* slider to *Slow*.
2) Describe this model of the hydrogen atom. What is the atom like?
   (a) There is a nucleus where the proton resides.
   (b) There is an electron in motion in a circular orbit.
   (c) There are several possible orbits the electron may follow.
   (d) All of the above.
3) Increase the speed just a little on the *Slow…Fast* slider. What happens when photons interact with the atom? Does the electron move?

4) Reset the spectrometer and allow the simulation to run for a few minutes. Describe/draw the experimental emission spectrum for atomic hydrogen below. Include the

regions/colors of the electromagnetic spectrum, approximate wavelength, and quantity of photons at each wavelength (each circle equals one photon).

5) Is this spectrum "right"? How does it compare to the experimental emission spectrum?

In the Bohr model, electrons can exist only at certain energy levels (also called shells), not at any energy levels between them. Shells in this energy diagram go from 1 to 6. An increase in energy level (say from 1 → 6) can only occur if a photon of incoming light is absorbed. A decrease in energy level (say from 2 → 1) is accompanied by the emission of a photon as the excited electron releases its excess energy.

6) In the "Help" menu, select *Transition* and fill in the missing entries on the table below:

Transition between n levels	**Wavelength (nm)**	**Region of Electromagnetic Spectrum***
1 → 2	122	UV
1 → 4	97	UV
2 → 3	655	Visible
2 → 6	410	Visible
3 → 4	1876	IR
3 → 6	1094	
4 → 6		IR
5 → 6		IR

*refer to the spectrometer

7) Referring to the "Electron Energy Level Diagram" in the upper right hand corner, sketch the electron energy levels, paying attention to the spacing of the energy levels. Include the n-value for each energy level.

8) Set the Light Controls to *Monochromatic* and reset the spectrometer. Look at the following transitions and answer the following questions for each:
   (a) What happens to the electron in the atom?
   (b) What happens to the energy level diagram?
   (c) What happens to the spectrometer?

   (i) Set the monochromatic light source to 122 nm. This provides photons of just the right energy to excite the electron from n =1 to n =2 shell (1 → 2 transition).

   (ii) Set the monochromatic light source to 103 nm. This provides photons of just the right energy to excite the electron from n=1 to n=3 shell (1→3 transition).

   (iii) Set the monochromatic light source to 97 nm. This provides photons of just the right energy to excite the electron from n=1 to n=4 shell (1→4 transition).

   (iv) Set the monochromatic light to 656 nm. This corresponds to a transition from 2→ 3. Why do you think you are seeing what you see?

Schrodinger's Model

Erwin Schrödinger began working on wave mechanics in 1925. His interest was sparked by a footnote in a paper by Albert Einstein. Like de Broglie, he began to think about explaining the movement of an electron in an atom as a wave. In 1926 he published his work, providing a theoretical basis for the atomic model that Bohr had proposed. The equation at the heart of his publication became known as Schrödinger's wave equation.

1) Describe this model of the hydrogen atom. What is the atom like? (Choose all that are correct)
   (a) There is a nucleus.
   (b) The electron is a particle in a well-defined orbit.
   (c) The position of the electron is represented in an ambiguous manner. Different areas are shaded.
2) What happens when photons interact with the atom?

3) Are the energy levels different when compared with Bohr's mode? Sketch the energy levels below:

Bohr's Model	Schrodinger's Model

4) Reset the spectrometer and allow the simulation to run for a few minutes. Describe/draw the experimental emission spectrum for atomic hydrogen below. Include the regions/colors of the electromagnetic spectrum, approximate wavelength, and quantity of photons at each wavelength (each circle equals one photon).